TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909 : INCORPORATED 1930.

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32 VICTORIA STREET
LONDON SW1

NOTES ON RECENT MEETINGS AND EVENTS

General Meeting in London.

A meeting of the Society was held in the Lecture Theatre of the Institution of Mechanical Engineers, Westminster, S.W.1, on Tuesday, December 8. The chair was taken by the President at 7 p.m.

The minutes of the last meeting having been taken as read, the names of applicants for membership were presented in the usual way.

The President then called upon Mr. P. Freedman to present his paper entitled "Low Voltage Neon," which was illustrated by numerous demonstrations. On the motion of the President, a cordial vote of thanks was passed to Mr. Freedman for his paper.

An interesting discussion followed, in which the following took part:—Capt. C. Higgins, Dr. J. W. T. Walsh, Mr. N. Bowtell, Professor J. T. MacGregor-Morris, Mr. C. A. Morton, Mr. N. Clack, Mr. D. C. Mandeville, Mr. F. P. Bentham, Mr. G. H. Wilson, Mr. W. J. Rickets, Mr. A. R. Ramgabe, Mr. J. S. Dow.

Mr. Freedman briefly replied to the discussion, and the meeting then terminated.

Applications for Membership.

Elections Pending.

At the general meeting of the Society, held on December 8, the names of the following applicants for membership were presented:—

CORPORATE MEMBERS:—

Head, O. W. .....3, Bernard Avenue, West Ealing, LONDON, W.13.

Hunt, R. W. .....19, Dolphin Road, Slough, BUCKS.

Score Smyth, J. B. ...22, Craven Hill Gardens, LONDON, W.2.

COUNTRY AND FOREIGN MEMBERS:—

Ette, F. S. .....103, Dovehouse Lane, Solihull, WARWICKSHIRE.

Forsyth, J. C. .....Municipal Electricity Department, P.O. Box 526, Christchurch, NEW ZEALAND.

ASSOCIATES:—

Dowling, W. G. B. ...25, Bedford Square, LONDON, W.C.1.

Pitt, F. H. G. .....250, Carlton Avenue, East Wembley, MIDDLESEX.

Stockall, K. J. .....Cleobury, Manor Road, Potters Bar, MIDDLESEX.

Elections Completed.

At this meeting the names of those announced on November 10, which were published in the issue of the Transactions (Vol. I, No. 12, p. 179, December, 1936) were read again, and these applicants were formally declared members of the Society.

Further Special Sections.

The Council has approved the initiation of two additional Special Sections, operating on the same lines as that at present devoted to Photometry. The two new sections will deal respectively with Industrial Lighting and Public Service Lighting (the latter title to include various other forms of lighting besides street lighting, which fall within the province of the municipal engineer) Further information in regard to these sections will be issued shortly, and members who wish to be attached to either will be asked to send in their names to the honorary secretaries. In the meantime particulars of the first meeting of the Section on Industrial Lighting on February 9 are given below. An opportunity for the initiation of the Section on Public Service Lighting will occur on March 13, when several papers on street lighting will be read.

Forthcoming Events

Jan. 12th. MR. J. W. HOWELL on **Some Important Considerations in Colliery Lighting.** *(General Meeting of the Illuminating Engineering Society, in the Lecture Theatre of the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.1);* **6.30 p.m.**

Jan. 12th. MR. R. O. ACKERLEY on **Some Aspects of Architectural Lighting.** *(Local Sectional Meeting of the Illuminating Engineering Society, Dublin).*

Jan. 14th. Local Sectional Meeting of the Illuminating Engineering Society *(at the Cadora Restaurant, Union Street, Glasgow);* **7.30 p.m.**

Feb. 9th. MR. H. C. WESTON on **Lighting and Industrial Performance.** *(Meeting of the Industrial Lighting Section of the Illuminating Engineering Society at Watson House, Townmead Road, Fulham, S.W.6);* **6.30 p.m.**

Feb. 12th. Informal Social Evening of the Illuminating Engineering Society *(at St. Ermin's Hotel, St. James's Park, S.W.1);* **6.30 p.m. Tickets 2/6 each.**

Feb. 17th. MR. G. H. WILSON on **Road Lighting and Road Surfaces.** *(Meeting of the Institute of Civil Engineers (Manchester District) at 36, George Street, Manchester);* **6.0 p.m.**

Feb. 18th. MR. P. FREEDMAN on **Low Voltage Neon.*** *(Local Sectional Meeting of the Illuminating Engineering Society at Cadora Restaurant, Union Street, Glasgow);* **7.30 p.m.**

Feb. 22nd. MR. G. T. WINCH on **Some Practical Aspects of Precision Photometry.** *(Meeting of the Photometric Section of the Illuminating Engineering Society at the Research Laboratories of the General Electric Company, Ltd., Wembley).*

Feb. 23rd. MR. HOWARD LONG on **Diffusion and Shadows.** *(General Meeting of the Illuminating Engineering Society at the E.L.M.A. Lighting Service Bureau, 2, Savoy Hill, London, W.C.2);* **6.30 p.m.**

**Repetition of paper read in London on December 8th, 1936.*

FACTORY LIGHTING AND ACCIDENT PREVENTION

by E. W. MURRAY, A.M.I.E.E.

H.M. Engineering Inspector of Factories (Home Office Industrial Museum)
(Member)

(Paper read on Tuesday, November 10th, 1936.)

The improvement of the illumination in factories and workshops is one of the subjects upon which the factory inspector is often asked to give advice, and it is encouraging to learn that the requests for information increase year by year.

It is not proposed to deal with the subject of industrial illumination in any of its more technical phases, but rather from the common-sense point of view, embracing methods which have been found in practice and have had to be altered to achieve the desired results; ideas which are being used with much benefit to the workers; and also a forecast of what might be expected in the future. both as regards artificial and natural illumination.

Education in Illumination.

In the first place, there is an important fact which must be borne in mind: illumination education proceeds at a very slow pace. It would, indeed, be very gratifying if people were as quick to follow the improvements in lighting as are the womenfolk to follow fashion. A few years ago shopkeepers realised that the public, when viewing their shop-windows, could not see the goods displayed therein to advantage, because they were, more or less, blinded by the glare of the lights in the window. The result is that now there is some difficulty in ascertaining the source of the lighting. In addition, the intensity of illumination has increased to a higher and perhaps a more pleasing figure. This improvement has gradually spread into the homes, but it has taken a few years to propagate so far. This follow-my-leader process eventually takes root in the industrial field, but it appears to require a further period of years for the improvements in the home to be adapted to the requirements of lighting factories. In order to increase the interest in this subject the Illuminating Engineering Society intends to start an industrial lighting section, and, through that medium, to enable those who are concerned with factories and workshops to become more "illumination conscious"—to use a present-day phrase.

The progress made during the last ten years in shop-window and display lighting has been tremendous, and much the same might be said about street and decorative lighting in the theatre and cinema, and some homes, but, unfortunately, as has already been mentioned, the same progress has not taken place in the factories. It cannot be hoped that factory lighting should follow the lines of cinema lighting for instance, but there are a number of points of principle that could be followed with great advantage. The usual complaint, when improvements are suggested for the illumination of a factory, is that there is no money to spare for such services, but since the same excuse is usually given for any suggestion whatsoever, it is only by mentioning the matter a sufficient number of times that some improvement is attempted. The same might be said about machine guarding generally, but eventually, when the guards are fitted, it is frequently said, "Why haven't we done this before?"

Accuracy in Fundamentals.

Now a word of advice. "Be sure of your ground when you are putting forward a scheme for improving illumination." It is so easy for a superior to turn a scheme down, or, in other words, to give it the "cold shoulder," and, in many cases, it is due to the persons putting the scheme forward not having made themselves conversant with the particular matter. It is well to try to see clearly the objects which the operatives are expected to see under the worst conditions, or at the end of the day when their nerves are perhaps a little wrought. A casual glance is useless. It is an easy matter to strain the eye for a short time, but do so for hours on end and one will find that it is little wonder why some operatives complain of eye-strain and headache.

If this method is adopted one will be sufficiently justified to deal adequately with a refusal to approve a scheme. One can take a leaf from the politician's notebook—and be prepared to fight tooth and nail for the "Yea," and to cast a deaf ear to the "Nay."

Remember, also, that no amount of illumination will ever correct a person's defective vision, so that a scheme will therefore be for persons who have, for all intents and purposes, normal vision, or vision corrected by glasses to this condition. In addition, adult workers will generally require more illumination than juveniles, since the latter have a keener sense of vision.

Also, one will want to know something about the amount of illumination required for some particular class of work. A number of guides of this nature are published by, and can be obtained from, the usual electricity or gas concerns, and these publications give suggested illumination values for practically every industrial process. Another guide is that issued by the Illuminating Engineering Society, and there are two others issued by H.M. Stationary Office. The latter publications give the findings of a Departmental Committee* set up to give recommendations for the lighting of factories and workshops. These reports should be in the hands of everybody who has authority in any business, since they give the minimum standards of illumination for all kinds of work. If the illumination figures suggested in these reports are compared with those in the other publications mentioned, one will observe

* The second and third reports of the Departmental Committee on Lighting in Factories and Workshops.

that for any particular class of work there is a great difference between them. It has been already emphasised that the figures in the Government reports are the minimum illumination values only, whilst the other figures are a guide for designing new installations. Lamps and mantles age and get dirty or broken, burners fill up with dust, reflectors discolour and become dirty, and, in times of heavy load, the gas pressure or voltage falls, and all these items seriously decrease the illumination with little or no reduction in the running cost. So that, if an installation is designed from the minimum figures and allowances are made for the ageing of the light sources, the discolouring of reflectors and the decorations and the dirt, it will probably be found that one will arrive at an initial figure which will indicate that the figures referred to in the Government publications are only apparently low.

It is frequently stated that the sense of sight dominates the activities of the worker, and that its processes call for the expenditure of more human energy than does any other sense. Good illumination is therefore a real necessity in order at least to relieve the high and unnecessary expenditure of energy which always accompanies a badly-designed or glaring installation. Many instances can be cited where improved illumination has resulted in an increased output, and these improvements must have been accompanied by a reduction in fatigue. Some of the Industrial Health Research Board's Reports give supporting evidence on this point, and in one case an increase of about 15 per cent. in output was obtained when the illumination was raised from 5 to 23 foot-candles.

Further, it is hoped to show how much easier and quicker the work can be seen when the illumination is increased. Again, when even rough work, which calls for very little discrimination, is performed, it is possible to obtain increased outputs with improved illumination, the new scheme often producing a more pleasing atmosphere in a workroom.

Natural and Artificial Illumination.

Now, this does not mean that the intensity of the artificial lighting need be as high as that of natural illumination, but one should try at least to copy the qualities of natural lighting, particularly to avoid glare and patchiness or great contrast; so that the best lighting scheme that can be adopted is good general lighting; in other words, if one copies the natural lighting conditions which one would obtain if one had a top-lighted building, or a building without a roof (weather permitting), one cannot be far wrong. On the other hand, however, the design of a building, or the position of the windows, may adversely affect the natural illumination in a room, yet one seldom hears of complaints about natural lighting. Why? The writer has often thought about this point, and has come to the conclusion that people usually consider any defects, if they are ever realised to be inevitable, with the result that they do not complain. As an instance of a complaint of natural lighting, there was an office about 16 feet square and 14 feet high which was provided with two long but narrow windows in the outside wall. These windows were hard against each side wall and a large blank wall space between them. The window frames were practically flush with the inner wall surface, so that there were no revills which could be whitened. The high contrast between the sky, which came into the field of vision through the windows, and the dark wall in between was the cause of the trouble. The occupants had complained, with the result that it was thought that the artificial illumination was at fault. Nothing was further from the mark. Arrangements were made to provide for some borrowed light by a glazed partition (diffusing glass) on one of the side walls. In addition, the clear glass in a partition opposite the outside wall was changed to frosted glass. These changes cured the defects by reducing the contrast between the window brightness and the other illuminated portions of the room. It would have been possible, in some measure, to have provided some form of artificial illumination to have remedied the defects, but then the cost of the illumination would have been very high indeed. In fact, it is in such cases as these that more artificial illumination would be required during the daylight period than during night time.

It may seem a divergence to mention this matter concerning daylight, but, in many instances, both natural and artificial illumination have to be considered together.

Reference may be made to one other case, due to poor natural lighting, particularly, as has been already mentioned, that trouble from this source is frequently overlooked. The case concerns a factory which is top lighted, and a number of power presses are fixed in rows along the shop and parallel to the top light. Now, the overhead gear at the top of the power presses throws shadows on the working areas or dies, and the illumination readings, taken during natural lighting, were 65 foot-candles in the gangways outside the presses, and 0.75-0.6 foot-candles on the dies. These readings were taken on a dull rainy day, and it was interesting to note that it was on such days as these that complaints were made by the operatives. Naturally, the management pooh-poohed the idea because they had viewed the complaint from the general illumination in the shop, and not from the operative's viewpoints. Further, the operatives had to look through the power press guards to endeavour to see their work. The brightness on their side of the guards was naturally higher than that on the dies or the work within the guard. Here, again, the trouble was the high degree of contrast. This is another case where artificial illumination of a high order is required on the dies during daylight, in order to reduce the illumination contrast in the operative's field of vision. Following up this idea, the high artificial illumination on the bottom dies, if used during the dark hours, would have required, in turn, a reasonably high artificial illumination in the shop, or the contrast would have persisted; but in the opposite direction—so it follows that the illumination

on the dies should be equal to, or a little higher than, that of the general shop area. *This could perhaps be remedied by the use of the double filament lamps as now used in the motor industry for head lamps.*

Requirements in Certain Industries.

On occasions it is found that factory occupiers are not always aware that the provision of suitable and adequate lighting is called for in many of the regulations made under the Factory Acts. The following are some of the industries mentioned: Building, Shipbuilding, Chemical, Vitreous Enamelling, Pottery, Fruit Preserving, and in dock premises, together with certain requirements as to lighting where locomotives and milling machines are used. Further, in factories where woodworking machinery is in use the regulations call particular attention to the need of good illumination, both natural and artificial, and they also stress the disadvantages of shadows. It will doubtless be appreciated that an increased accident risk is likely to arise through poor illumination, or shadows, with such high speed cutters, saws, etc., as are used in the woodworking industry. Nevertheless, there is still a fair amount of work yet to be undertaken before industrial lighting can be considered satisfactory, although admittedly there are quite a number of excellent installations provided in some factories.

Some idea of the inadequacy of the lighting in a large proportion of our industrial establishments is shown on a chart exhibited in the Home Office Industrial Museum. This chart records monthly the reportable accidents in factories and workshops. The increase in accidents during the winter, or the months when artificial lighting is necessary, is very noticeable—a large proportion of these accidents being due to persons falling.

Imperfect Lighting and Accidents.

Perhaps the writer might be permitted to mention the details of a particular accident which came to his notice some while ago. A corridor in the centre of a building was lit in day time by "borrowed" light from glazed partitions. In this corridor there were two steps and recently a hot water pipe had been installed at high level across the corridor and parallel with the steps. The light for the corridor had been rightly placed above the steps to ensure good illumination on them. Unfortunately the light, the pipe, and the top step were in line vertically so that a shadow of the pipe was thrown along the nose of the top step and to a quick glance the step was unobservable. Needless to say there were a number of falls at this spot during the winter, but it was only following an accident to a new waitress who had fallen with a tray of crockery and injured her face that the matter was investigated and the position of the light altered. In addition, the shallow conical reflector was replaced by an enclosing bowl which eliminated the hard shadow.

The disposition of lights for a working area should be carefully selected and placed so that the operative is not troubled by shadows of parts of the structure, or even of himself, and particularly by shadows of moving objects. The effect on one's nerves and the consequent fatigue involved of an erratic moving shadow must not be lost sight of.

A flickering light, due to quick variations in mains pressure, may be just as nerve racking as a moving shadow, and this is not an uncommon fault to be found in factories. Instances of this nature occur in both gas and electrical installations. In the case of the latter, the trouble is usually due to a bad joint or the need of a flywheel to smooth out the speed variations of the works' transmission gear.

Shadow Conditions.

But shadows are not always so undesirable. In a few industries they are very necessary in order to show details, in very much the same way that an architect depends on the shadow effects, produced by the sun, on his building.

A typical case of this nature is drilling. An account of a case where a complaint was investigated may help others to avoid making the same mistake. The building in question was the drilling shop of an engineering works. This section had been rewired for a general lighting scheme of some 8 or 9 foot-candles illumination. The old scheme consisted of individual lights at each machine, some machines having portable leads and hand lamps without reflectors. The drillers' complaint was that they could not see their work as easily as with the old scheme.

Needless to say, the managers were much perturbed at the complaints, and they were at a loss to understand the reason, particularly as they had taken readings of the illumination with the old scheme and the new. The trouble here was entirely due to the good general lighting scheme. The indentations made by the centre-punch marks ("centre pops") were as evenly illuminated as the surface of the metal, so that the drillers had to find the indentations with their fingers and then to move the drill over this position, trusting to luck that the centre of the drill and the centre punch marks were in line. A pocket battery hand-lamp indicated the usefulness of directional lighting by illuminating one side of the centre-punch marks more than the other. This showed the drilling marks quite clearly.

Directional lighting to produce shadows on the work is required in many industries, and, as a guide, it may be taken that directional lighting is necessary in all cases where the unevenness of a surface is the point of importance. Some of the industries in which shadows are a distinct help to the operatives are printing, embossing, weaving, goffering, fustian cutting, drilling, carving, etc.

The provision of proper illumination on the work can influence the efficiency of guards for many dangerous operations on machines. The case may arise where the shadows thrown by the guards are a disadvantage. If wire mesh guards are used it is quite possible that shadows would not be so sharp if general lighting is installed. It would be quite different with individual lighting. It must be remembered also that any lighting scheme will give a higher illumination on the outside of the guards than on the work within the guards, and this must naturally in-

crease the difficulty from the worker's viewpoint, since he has to look through the guard to see his work. (See Figs. 1 and 2.) It follows, therefore, that where there is any form of screen between the operative and his work then some form of lighting should be provided on the side of the screen remote from the operative. If time permits it is proposed to show some examples of this type of lighting. Great importance should be attached to the direction of the light on to the work in the same direction as that in which the worker is looking. To instal lights at the back of machines is very bad practice, because the operative has to contend with the reflected glare all the time that artificial lighting is in use.

Artificial lighting is not alone in causing this trouble. The writer has seen some works where the machines are placed with their backs to the windows. If the windows are on the sunny side of the building trouble from reflected glare is almost certain to be present in daytime. In addition, an unsuitably shaded source of light plays an important part in the field of safety. A glaring light is always a hindrance to vision, and unfortunately is a very common fault in lighting installations. The glare from a light distracts from an otherwise adequate illumination level. In order that glare may be the more easily detected, it may be roughly defined as any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision or eye fatigue.

Lights without reflectors, or the use of shallow reflectors on the light sources, should never be allowed. In fact, the light source should be one of those things that the eye should not see.

Explosion Risk.

It was only a few years ago that the provision of artificial lighting in buildings where inflammable vapours or explosive dusts existed proved a trying problem. Such buildings were usually artificially lit from the outside of the windows. Of course, such risks as these have existed in mines for many years, and, as a result of the activities of manufacturers and the work done by the Safety in Mines Research Board there are now a number of electrical fittings and accessories on the market which are suitable for use in these atmospheres.

The main principle in the design of this class of fitting is to arrange for it to be possible for an explosion to take place inside the fitting without exploding the external atmosphere. This is accomplished, as shown in Fig. 5, by using wide metal flanges between the main component part of the fittings, and for the flanged ends to be bolted together without packing. The cooling effect on the hot gases by contact with these wide flanges is such that the temperature of any gas or other vapour leaking out, through the flanges, is so low that it cannot ignite the external and normally explosive atmosphere. Accessories can be designed for the following gases when mixed with air:—

1. Methane.
2. Petroleum and acetone vapours.
3. Coal gas (town's gas) and coke-oven gas.

Very Fine Work.

There are many instances where work of a very fine nature is executed in which it is not possible to overcome the difficulty of "seeing the work," by illumination alone, and a number of the more progressive industries are providing their workers with special magnifying spectacles. If one attempts to see the fine details of the threads in woven silk, or artificial silk, or the fine wires used in wireless components, or even in burling and mending, it will be found that the object has to be held quite near to the eyes—say some 6 to 9 inches. To do this very infrequently renders the fatigue of the eye almost unnoticeable, but the more or less intensive requirements of the industries referred to are quite a different matter. This problem was the subject of a special investigation by Mr. H. C. Weston, of the Industrial Fatigue Research Board, now the Industrial Health Research Board, and is very ably explained in Report No. 49 on "The Relief of Eye Strain among Persons performing very fine work," published by the Stationery Office. The principle employed is, in a measure, the use of magnifying lenses, and when these are properly and correctly fitted to suit the individual worker's normal vision they afford a marked help to the operatives in reducing the fatigue of the eye to the angle of convergence and accommodation.

Inspection of Polished Surfaces.

The detection of flaws, scratches or blemishes on highly polished surfaces, such as arises during the inspection of sheets of stainless steel, aluminium, glass, or other materials which are large in area and flat, has been the cause of a number of complaints of eye strain and fatigue. These polished surfaces reflect the source of illumination upwards into the workers' eyes, and the trouble is due to the contrast in brightness seen on the surface. It is necessary, therefore, to provide light sources having large areas. For very large sheets a type of inverted trough about three feet wide and nine feet long, fitted with a translucent screen below the lights, as shown in Fig. 6, has given satisfaction. The illumination brightness of the screens used is about 3-4 candles per square inch. This figure could, perhaps, be increased a little, but to not more than 5 candles per square inch. Such a fitting can be likened to a portion of the north light sky; it has a large illuminating area of low brightness.

Low Voltage Lighting.

The provision of small low voltage lamps with reflectors for illuminating the working area of machines is steadily increasing. This method of lighting can be used to advantage on almost any type of machine, and is a useful asset in giving the worker some illumination in an area where it is most needed. It is most essential that the reflectors and lamps should be small because one of the main points to be remembered is that the light source must be between the worker and the work. The more general method of obtaining the low voltage is the use of the double wound transformer which may be attached to particular machines so that the voltage drop on

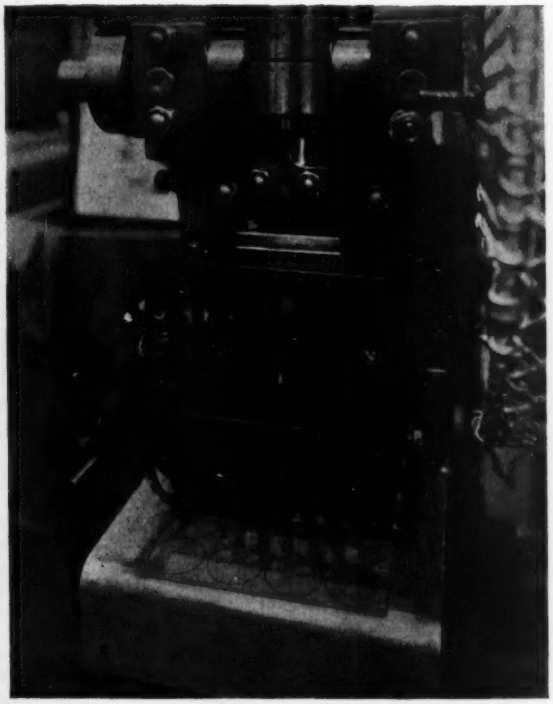


Fig. 1. Here the worker looks through the screen at the work, which receives no special illumination.

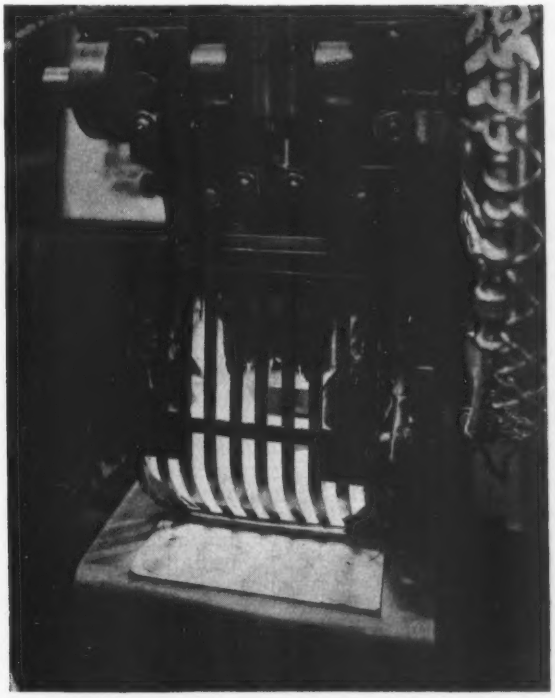


Fig. 2. The addition of local lighting behind the screen makes all the difference to the appearance of the work.

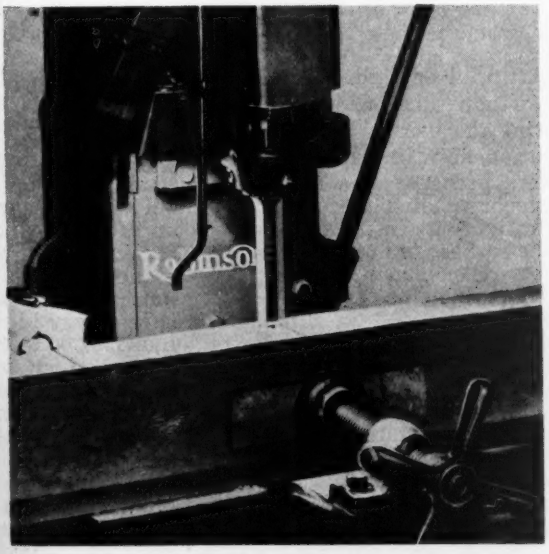


Fig. 3. Showing the value of local lighting for a mortice chain grinding machine.

Fig. 4. A Band Saw likewise furnished with local lighting from miniature unit.

the secondary winding is negligible. If the secondary winding is designed for 12 volts, " bus " lamps should be used, because they have a longer life than motor car lamps, but are, however, a little less efficient, i.e., they take more current for the same illumination. To summarise, the advantages of this form of lighting are (1) being small, the lamps and reflectors can be placed between the worker and his work, the beam of light being thrown in the direction in which he is looking, so that he is not subjected to reflected glare from the wet, oily, or other shiny surface of the work or of the machine. (Direct reflection always occurs in directions *away* from the worker.) (2) The light can be placed in the optimum position. (3) Current consumption is low, and maintenance costs for renewals also low, compared with normal voltage lamps. (4) There is little risk of electric shock, particularly if one of the secondary terminals is " earthed."

Some manufacturers of machine tools, woodworking machinery, and sewing machines have incorporated a light of this nature in the design of the machines. Continental manufacturers are following suit. And, in cases where the machines are electrically driven by A.C. power, the motor stator may form the core of the transformer, and a coil (the secondary) is inserted into a slot milled into the outer side of the stator. The ends of this coil are taken to two terminals on the motor frame from where the light supply can be obtained.

This low-voltage local lighting should never be the only lighting in a room or factory. The suggested method is to provide in addition general lighting of the order of 2-10 foot-candles, according to the requirements. Examples of this low-voltage lighting are seen on page 7.

Lighting of Textile Processes.

Until about a year ago the engine-room of a certain factory in the South of England was illuminated by oil lamps of a decidedly antique pattern. These were some four or five oil-burning lamps, such as one sees the firemen on the locomotives using when they want to trim the coal. These were placed about the engine-room, and, to make matters worse, the smoke from these lamps had produced a more or less ideal black surface on the walls and ceiling. Fortunately, owing to an increase in trade, the old mill had to be demolished, and is now replaced by a building of modern design and equipment, the lighting scheme being in direct contrast to the old one.

More recently, in a few lace factories in the Midlands the use of candles was fairly general. All the threads on the lace-making machines have to pass through separate holes in a type of guide or reed plate, which is placed about two feet from the floor at the back of the machines. The machines are generally placed back to back, and, because of the overhead mechanism and the side frames, there is little natural or artificial illumination available from the normal room lighting. In the cases mentioned, the workers, in order to repair a broken thread, had resorted to holding a small metal plaque, something like the lid of a condensed milk tin, between the lower joints of the first and second fingers of the left hand, and a lighted candle was affixed to the centre of the metal plaque. The operatives could then hold the light quite near the reed plate, and re-thread, or piece together, the broken thread. When light-coloured threads were used, this process was fairly easy, but there was a little difficulty with the darker threads owing to the want of contrast. The operative had to be extremely careful not to set alight the nearby threads with his candle.

The latest development for lighting this class of work is to instal permanent lights with small trough reflectors within the machine, or, alternatively, portable low-voltage handlamps, provided with a ring to fit over the middle finger, or a loop to go over the hand, are used. These methods of supporting the lights leave the thumb and first finger free to deal with the threads.

The threading of reed frames for looms is another case where an improved method of lighting is required. The writer has not yet seen a good installation. During day time the operative sits with the work between him or her and a window, across which is stretched some white gauze or tissue paper, and in this way the heels in the reeds, which are similar to the eyes in needles, can be seen easily and threaded. There is no reason why a more or less translucent screen, illuminated from the back with lights and suitable reflectors, should not be used during the dark hours. Incidentally, this arrangement just described is used fairly generally in bottling rooms, and it is reported to have led to reductions in the complaints from customers finding foreign matter in their favourite beverages.

Artificial Daylight.

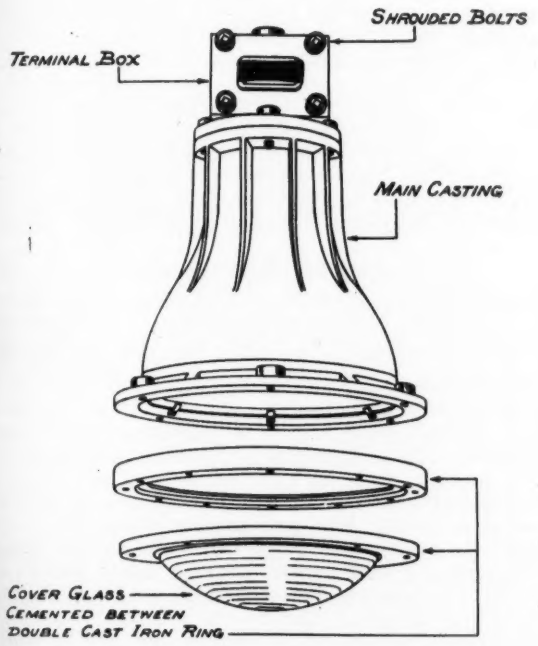
Artificial daylight is at least constant, and this is more than can be said of natural lighting, particularly during the greater part of the present year. Such lighting, however, should be confined to special areas, where perhaps some form of inspection of colours or goods is being executed. A general artificial daylight lighting scheme for a large room is often found to be rather cold and depressing. The inspection of safety razor blades is one of the industries were artificial daylight has proved very suitable. In some of these installations the illumination is of a very high order of intensity, being in the region of 150-200 foot-candles. The inspection is usually carried on in small cubicles, each with its own light, and the cubicles are lined with black velvetine, in order to cause the minimum of distraction to the eyes of the operatives.

A few years ago some inquiries were being made about lighting in weaving sheds, and in a few instances the workers expressed their preference for working at looms which were lit by gas. The reason for the choice was thought to be due to the whiter light from the gas mantles; but, quite possibly, the radiant heat was one of the important factors—it was winter time. The gas concerns have full knowledge

of this point, and they have a rather useful form of fitting that can be adjusted to give more or less radiant heat when it is alight (see Fig. 7).

Natural Lighting.

The tendency in modern design of factories is to increase the area of the windows and, while this is very satisfactory from the safety, health, and welfare sides, generally some special treatment is necessary during the few hot summer days to reduce the solar heat and glare of the sun. In winter the large expanse of glass also calls for the provision of additional heating, if the proper output of work is to be maintained. The effect of the sun's glare, and, incidentally, the heat, can be reduced by colour-washing the glass, or improvising blinds

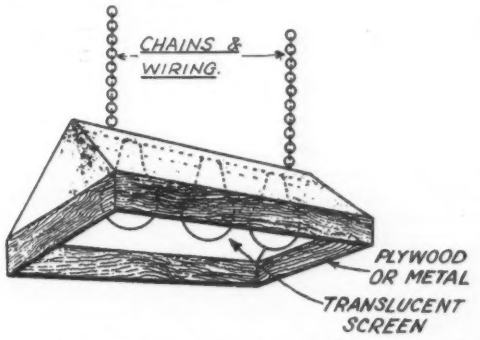


F9791-200 WATT FLAMEPROOF PENDANT FITTING
BUXTON CERTIFICATE NO. F.L.P.541.

Fig. 5. Showing essential parts of explosion-proof fitting.

on the outside of the windows. In some cases a permanent canopy of suitable width has effectively shaded the upper portions of windows, and in others the use of radiant heat-resisting glass has proved satisfactory. One of these glasses also proves to be a very satisfactory light disperser, and, in addition, has the advantage that it presents a good, white surface on the inside. It is, therefore, a good reflector for artificial illumination during the dark hours.

The use of dispersive, or prismatic, window glass is not used to the extent it should be. In many old buildings, where the ceilings are low and the rooms



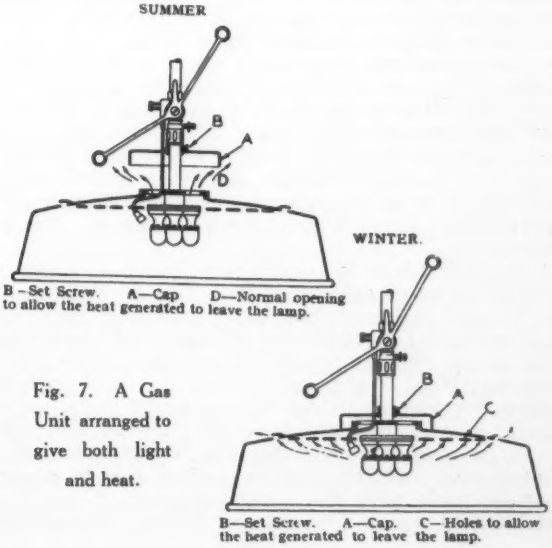
Translucent screen - tracing cloth or frosted glass. Tracing cloth is easily and cheaply renewed. Frosted glass should be wired in case of breakage.

Fig. 6. Type of fitting for the inspection of polished surfaces.

deep, these types of glasses can provide valuable improvements in natural illumination. With clear glass the angle at which the light reaches the tables or benches at the back of the rooms is the frequent cause of complaint due to the contrast within the field of vision. Dispersive glass avoids this trouble.

Maintenance.

In the early pages reference was made to the illumination reduction due to dirt and dust. It is unfortunate that the old statement, "that soap and water are cheaper than the energy required to provide light," is not yet fully realised. This applies equally to windows, lamps, reflectors, and shades. Factory occupiers have sometimes been astounded at the increased illumination after a thorough cleaning of the light units. Such demonstrations are usually better accomplished



B—Set Screw. A—Cap D—Normal opening to allow the heat generated to leave the lamp.

Fig. 7. A Gas Unit arranged to give both light and heat.

with the aid of a lightmeter, and, as an outcome, firms have purchased lightmeters which are passed on to the managers of the different shops with a log book. The illumination readings at specially selected points in each shop are recorded monthly, or bi-monthly, and, in this way, enable the directors, or other persons concerned, to deal with the cleaning and the renewal of aged lamps before the illumination becomes too low with its possible influence on the accident rate.

Electrical Accidents.

The writer has been asked to add a few words on some of the electrical accident risks that arise in factories, and, since this could be the subject of a paper occupying a full evening, it is proposed to deal with the subject from the point of view of lighting only.

The extended use of alternating current has made it much more important to ensure that any metal, which is likely to become alive accidentally, is efficiently "earthed." In other words, frequent inspection is necessary to ascertain that the efficiency of the earthing system is maintained. If a fault develops in the circuit wiring, the fuses operate and afford a warning that something is wrong, but if the earth wire is making a poor connection, or gets broken, there is nothing to indicate the fault (except maintenance), with the result that a person receiving a shock is often the first indication of danger.

The metal lampholder is, perhaps, the most common cause of accident, and this can be confirmed by a visit to the Home Office Industrial Museum, where a number of these holders are exhibited, each of which has caused a fatal accident. One can never be sure that the insulation of the holder is being maintained in a safe condition. Metal switch-holders are particularly bad since they entice one to grip the holder in order to switch on or off. Every effort should be made to substitute the insulated lampholders for the metal ones where they are within the reach of persons who might accidentally touch some form of promiscuous "earth." An "earth connection" does not necessarily mean a contact with a water-pipe or an electric conduit, although the writer has seen cases where even these have had a high resistance to earth. Metal bell pushes and crank bell pulls may often provide good "earths," and in factories such items as shafting, machines, metal storage racks, and metal cupboards, conveyor frames, and many others provide an "earth" where it may be unexpected.

The screw-cap lampholder without a skirt is another piece of apparatus that it is as well not to touch until one has made sure that both leads are isolated from the supply by switching off the double pole main switch, or by withdrawing both fuses from the local fuse board. There are five ways in which a screw cap holder can be wired, only one of which is correct, and even this method is at the mercy of the supply authorities, who occasionally change over the live and neutral mains, to ensure that the main with the lower resistance to earth is the neutral one. The skirted holder reduces the anxiety one may have over this matter, although the apathy of many people, who continue using the bad types, is alarming.

Portable Lights.

There is no reason whatsoever why a person should walk about with a portable light and lead, which is a veritable "death-trap." Every manufacturer nowadays makes portable lamps which comply with the Home Office requirements. The use of improvised portable lamps has been responsible for a fair number of fatalities. Electricians themselves form a high proportion of these fatalities. Low voltage handlamps are a great boon on the side of safety, and even if there are no three-pin plugs available, the transformer can be mounted inside a wooden box so that the contacts, metal core, and clamps, etc., cannot be touched. This type of portable light is particularly suitable for use inside boilers, where the worker may be perspiring freely if the boiler is not quite cool. In a prone position the area of contact with the boiler of the worker's body clad with clothes, and wet with perspiration, is so large as to make it a somewhat hazardous job if a normal voltage handlamp is used. Even with a good type of handlamp the lamp may get broken and the worker, being in the dark, may touch the filament.

Portable Appliances.

The use of all types of portable electric appliances must be considered unsafe unless they are "earthed." There are a number of so-called insulated appliances in use, concerning which it is often stated that they are quite safe and need not be "earthed." Appliances of this type have the metalwork covered with a coating of bakelite, or similar insulating material, but it is impossible to prevent corners or edges of the insulating material being chipped or cracks developing in it. The perspiration from the user's hands can percolate into these cracks so that these appliances are often used with a false sense of security. In order to be on the safe side, an efficient "earth" terminal should be demanded and used.

The maintenance of these appliances should never be entrusted to the amateur electrician, or ever be allowed to be undertaken by the ordinary users. Cases have been known where the lead having been broken, the "live" wire has been attached to the earth connection on the apparatus.

A great deal might be said against the suppliers of portable appliances, who provide a three-core cable but fit an adaptor with a so-called "earth" plate on it. The unsuspecting buyer thoroughly believes the apparatus to be perfect and in accordance with the best electrical practice. It is often a sad disillusionment when he is informed that if the insulation of the appliance, or the holder to which it is connected, breaks down, both of them may be alive to earth and therefore dangerous.

The writer has been asked to deal somewhat fully with electrical risks and safeguards against them, because the facts are not sufficiently realised by non-

technical people, and it is expedient to give them publicity. It is not, of course, meant to imply that other forms of lighting are immune from accidents, but in the case of electricity risks are less evident, and the need for instruction is correspondingly great.

One other point should be made absolutely clear. The risks described are all due to imperfections of apparatus or arrangements. It is easy to provide safeguards—if users would be careful only to avail themselves of first-class material and fittings of a safe character, which are at their disposal.

DISCUSSION

Mr. A. N. FOSTER (Vice-President of the Institution of Engineers-in-Charge), having conveyed the apologies of the President of the Institution in being unable to attend owing to an engagement at the Institution of Civil Engineers, and of Mr. Clark, who was indisposed, assured the Society how much the members of the Institution appreciated the opportunity of attending the joint meeting and of hearing the reading of Mr. Murray's paper, from which they would derive great benefit. The Institution, he said, could claim to be the Society's foster mother; to substantiate that claim he produced a copy of a paper read before the Institution on December 11, 1907, by the late Mr. Leon Gaster, who had become the Secretary of the Society subsequent to its formation in 1909. The title of that paper was "The Province of the Illuminating Engineer." Mr. A. P. Trotter, who was Electrical Adviser to the Board of Trade, had presided at the 1907 meeting. The Institution had persuaded Mr. Gaster to take its platform and to put forward his then very advanced views on the necessity for placing on a scientific basis the highly important subject of illumination, which, until then, had been nobody's friend. Commenting on a remark by Mr. Murray that progress in the improvement of illumination had been slow, Mr. Foster questioned whether it had been really slow when due regard was paid to the varied interests which had had to be reduced to one common denominator.

Mr. C. C. PATERSON (Past-President of the Society) directed his remarks to the point made in the paper that the suggested illumination values given in Government reports were minimum values only, and felt that, perhaps, the author had been a little more gentle than he would wish to be concerning the usefulness or otherwise of such guidance as was given in existing official regulations. Mr. Paterson hoped that one feature which had been impressed upon the minds of illuminating engineers in the course of their education and of their experience during the last ten or fifteen years was that it was folly to attempt to formulate definite scales and codes of lighting if they were to be regarded in any way as being permanent. He agreed that at different stages of our evolution certain scales seemed to have been regarded as being about right, but in five, ten, or fifteen years those scales had become very much out-of-date, and he believed we were coming to the view that the amount of light that could be used, and used profitably, for industrial work, was almost unlimited; we could provide, artificially, intensities almost approaching those of daylight, provided we could avoid great contrasts between the lightest and darkest surfaces. Therefore, he hoped that when we began to think again about the provisions of Acts and Regulations concerning lighting we should not attempt to formulate further minimum scales, but should be content merely to give the legal power to require adequate lighting. He believed that in every case in which minimum scales had been formulated those scales had had within a few years a very detrimental effect upon factory lighting. It was far better that those who had to guide industrialists should indicate what was regarded for the time being as good practice in lighting; the accepted standards of good lighting must always be far above the minimum standards which safety demanded. He was not sure that Mr. Murray had sufficiently clearly distinguished between what was required for safety and what was really good lighting for effective production purposes. If we tried to formulate scales of lighting which were considered satisfactory from the safety point of view, those scales tended to be accepted as suitable for effective industrial lighting, whereas they were never put forward as providing good industrial lighting.

Mr. H. C. WESTON urged that one of the most effective methods of preventing industrial accidents was the detection of accident-prone individuals and their employment only in occupations in which risk of accident was very small. Until that could be done, safety measures, including good lighting, ought to be devised not merely for the majority of employed persons, but with special regard to the protection of the accident-prone minority. Accident proneness was a matter of personal qualities, which could not be changed by good lighting; but good lighting could reduce the risks to which accident-prone persons and others were exposed. He mentioned a case in which seventy-six workers in one factory had had their eyes examined, and 58 per cent. of them were found to be suffering from refractive errors, which needed to be corrected. He suggested that if that were typical of industry as a whole, lighting installations ought to be planned for the protection of people having slightly subnormal vision.

Mr. F. E. SHAW (chairman of the Technical Committee of the Institution of Engineers-in-Charge) commented upon the improvements which had been made since he had entered the works thirty years ago, when the general lighting was by open arc lamps and the local bench-lighting by flat flame gas-burners, and when the shadows were so deep that one could dodge the foreman's eye by moving into one of them! He also pleaded for improvement in the street-lighting of a large number of our villages. He had often wondered, he said, when parish councils would wake up to the fact that good lighting was a necessary factor in our everyday life; and he recalled a conversation with a parish councillor who had been told that his village was dismal at night, and had replied

that the people should go out only when the moon was up, but should stay indoors when it was dark.

Mr. Shaw also inquired whether the trades unions had been interested in the provision of better lighting, and whether they had taken steps to that end. He pointed out that one of the reasons for the extensive use of opal shades was their cheapness, and he asked whether the low-price stores were able to sell very cheap reflectors. After expressing the hope that much good would accrue from Mr. Murray's paper, he said the Institution was glad to be associated with the Society and would do its best to carry the torch forward.

Mr. R. O. ACKERLEY, emphasising the author's advice to be sure of our ground when putting forward a scheme for improving illumination, said that that was one of the most important aspects of industrial lighting; in view of the diversity of tasks, one must know exactly what a man wanted to do and see in order to make a recommendation. General lighting would go quite a long way, but many special jobs required special treatment. Therefore, he asked factory engineers to help by indicating just what they wanted, so that the illuminating engineers could endeavour to provide it; the latter could not be experts in regard to all the industries of the country.

Commenting on the importance of shadow and side illumination in many industrial operations, Mr. Ackerley criticised the practice of putting forward lighting recommendations in terms of illumination on the horizontal plane, for he felt that we were neglecting to some extent illumination on the vertical plane. He suggested that the Society might arrange for an investigation into the problem.

With regard to flameproof fittings, he said that although, in many cases, it was better to be able to light from inside, rather than from outside, the interiors of buildings in which inflammable vapours or explosive dusts existed, the flameproof fitting was, by its nature, the most horribly inefficient type of fitting we could possibly use. It had a large mass of metal and a tiny hole, through which the light came, and he suggested that factories having north lights or ample window space could probably be provided with better general illumination by means of lamps fitted outside the windows than by means of a large number of small lights from flameproof fittings inside.

In asking what was meant by the author's comment that artificial daylight was at least constant, Mr. Ackerley said he agreed so far as intensity was concerned, but its *quality* was far from constant. In many cases light which had been referred to in the past as daylight was not a reproduction of daylight. Razor-blade inspection was mentioned in the paper as a task for which artificial daylight had proved very suitable. The light required for razor-blade inspection, however, was really something much more blue than tungsten light and not necessarily true daylight, and since the electric discharge lamp had been introduced, its blue light had been found to be of great advantage in many jobs from the point of view of visual acuity and sharpness of definition.

THE PRESIDENT intimated that Mr. Ackerley's suggestion for an investigation into the question of illumination on both the vertical and horizontal planes would be referred to the Technical Committee.

Mr. A. W. WYATT (Institution of Engineers-in-Charge) pointed to the fact that individuals varied in respect of the illumination they required for the performance of particular tasks as introducing a further complication into the illumination problem. He added that persons beyond a certain age could not have their eyesight corrected for all purposes, but needed several pairs of spectacles, which they should wear at different times according to the tasks they were performing. Another matter he commented upon was the difficulty of convincing people of the danger of using electrical apparatus if it were not earthed.

Mr. K. F. SAWYER discussed and illustrated some of the lighting in the new workshops attached to the laboratories of the Gas Light and Coke Co. at Fulham (London). A workshop he illustrated (Fig. A) contained a number of general purpose machines engaged on normal work, and good general lighting by means of gas lamps was provided. The maximum value of illumination was 17 foot-candles and the average value was 12 foot-candles. The whole of the heating was effected by means of gas radiant heat panels in conjunction with the gas lighting. He emphasised that gas lighting, having an average value of from 15 to 20 foot-candles, would take charge of the whole of the heating requirements of the normal factory, so that gas lighting could be considered as being almost given away as an incidental with the heating of a workshop or factory. Mr. Sawyer's illustrations also served to emphasise the good quality of lighting provided at the working plane by means of the general lighting system, and the almost entire elimination of troublesome shadows. Even the inside of a turning in a machine

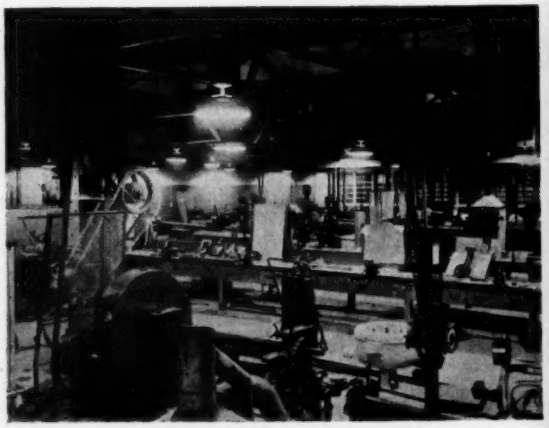


Fig. A. A section of a factory equipped with general gas lighting.

was illuminated to approximately 8 foot-candles, so that the operator could see what he was doing.

Mr. MURRAY took the opportunity to say that he was not opposed to radiant heating from above; indeed, he considered it rather valuable, though some people complained about hot heads and cold feet.

Mr. H. C. COOPER, who favoured the local lighting of machines, emphasised the saving that could be effected in respect of lamp renewals when using low-voltage lighting. Owing to space restrictions, the only mains voltage lamp available was the 15-watt Pigmy, which had a very fragile filament and failed quickly under vibration. The 12-watt bus lamp had a filament ten times as thick and obviously stood up to vibration far better. Motor car lamps were often over-run, so that their life was correspondingly short; if it were essential to use them for lighting machines in a factory, on account of their small size, he suggested they might be run at below their rated voltage.

Speaking of transformers, he said it was not always realised that fuses were required on the low voltage side. A transformer giving, say, 4 amps. at 12 volts had a short circuit current of over 30 amps., whereas the lamp wiring would probably be rated at about 5. A red-hot flex at 12 volts was just as bad as at 240 volts. Fuses on the high voltage side were of doubtful efficiency. High reactance transformers did not require fuses, but their voltage regulation was very bad—a matter of some importance. An over-voltage of only 5 per cent. reduced the life of the lamps by half, whilst under-voltage of 5 per cent. reduced the light output by 20 per cent. High reactance transformers were suitable for use, therefore, only with single lamps of pre-determined wattage.

Although, with the secondary earthed and fuses fitted, almost any sort of wiring would be safe, it was more economical to carry it out properly in the first instance. The difference in cost between a yard of cab tyre cable and a yard of the cheapest twisted twin flex was only 4d., which would not pay for many calls to the maintenance electrician.

Fig. B. Gas lighting in a clothing factory.

Mr. J. G. CLARK, whilst agreeing that in arranging the lighting of a workshop it was desirable to study the needs of the workmen, suggested that one should be careful not to take their views too seriously. Sometimes it would be found that their supposed needs were based upon wrong ideas. As an illustration of this he mentioned a case in which improved lighting was under consideration. The workmen themselves had expressed a strong view to the manager that any improved lighting should be by lamps of a movable type. Evidently they had been used to lighting units on double arm brackets, which enabled the light source to be moved into practically any position, and they could not imagine that any source of light could be successful which did not permit of movement. The manager was so impressed by the strong views of the workmen, who were high-class craftsmen, that it was considered expedient to put in a small installation of improved lighting, but possessing the facility of movement.

Fig. C. Another view of the clothing factory shown in Fig. B.

What actually happened, apparently, was that the workmen moved the lamp into various positions, but after a day or two they ceased to do this, having found a position which, with a new source of light, gave them everything they required in the way of illumination. This event proved, he thought, that the request for movability was founded upon the use of unsuitable light sources.

Mr. Clark next referred to the increased output that generally followed improved lighting. He suggested that it would be desirable to emphasise that mere increase in illumination would not lead to an improvement unless at the same time glare was not prevented. He felt sure that Mr. Murray would agree that this was so.

Mr. Clark referred to the valuable heat component from a certain type of factory lighting fitting. The

action of these lamps resembled closely the heating effect provided by overhead panels which had proved so successful in modern heating work.

With regard to the maintenance of gas lighting apparatus, Mr. Clark said that too often it was left in the hands of men who, although their intentions were good, had not the necessary knowledge. He pointed out that unless the proper attention were given to the equipment it might be just as well to give it no attention at all, and he urged that if it were not convenient for the maintenance to be placed in the hands of the local gas undertaking, the man responsible for the maintenance of the equipment at the factory should go to the local gas undertaking for a few hours' training, during which time he could learn which factors really mattered.

In conclusion, Mr. Clark illustrated a number of modern gas lighting installations, in a bicycle factory, a printing works, a foundry, a clothing factory,

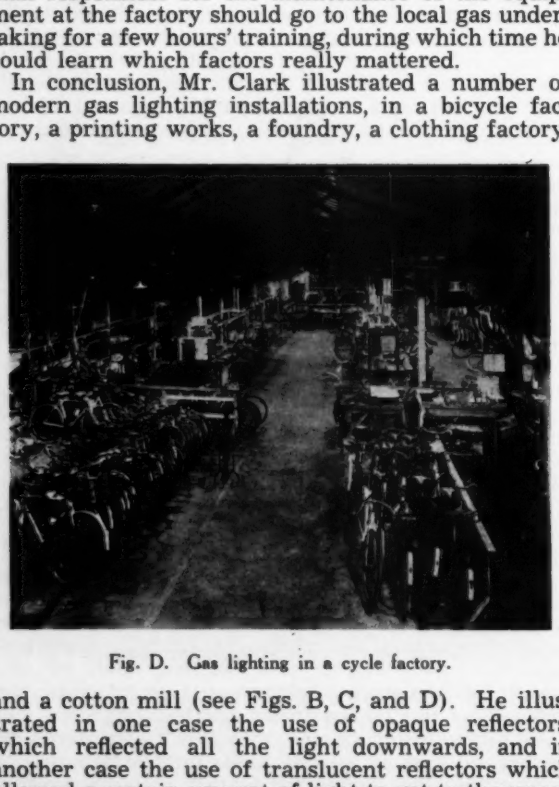


Fig. D. Gas lighting in a cycle factory.

and a cotton mill (see Figs. B, C, and D). He illustrated in one case the use of opaque reflectors, which reflected all the light downwards, and in another case the use of translucent reflectors which allowed a certain amount of light to get to the upper regions of the workshop—giving an effect of spaciousness which was not apparent in the previous case. At the printing works opaque reflectors were used and were so made that a certain amount of light reached the upper regions, but the effect was not so good as with the translucent reflectors. In all the illustrations good general illumination was provided and the machines were well lit; such shadows as existed were of very low density.

Mr. F. JACKSON was a little concerned about remarks made by Mr. Murray and Mr. Wyatt concerning the possible dangers of electrical equipment, and said that, having taken reasonable precautions, he looked upon the bright side. In order that the matter should be regarded in its proper perspective he recalled the recent Presidential Address of Mr. H. T. Young to the Institution of Electrical Engineers, in which it was stated that the number of people killed throughout the country in a whole year as a direct result of electricity was seventy-one, the number killed as the result of falling out of bed was ninety-two, the number killed by falling downstairs was 738, and the number killed as the result of burns—not electrical burns—was 897. He urged that we should not frighten ourselves by stressing the possibilities of accident, bearing in mind that reasonable precautions were taken.

Mr. J. S. Dow, commenting on the reference made to the interest of the trades unions in good lighting, said that the view had been expressed that some opposition on the part of the workers to schemes for improving the lighting might arise if they thought that an increased output would be expected from them. It appeared that a better way of presenting the matter to them—the advantages of good illumination—was that it enabled them to work more easily, safely, and with greater comfort, and removed a handicap to good work, which prevented them from putting forth their best efforts.

Mr. Dow also asked whether, as the result of experience at the Home Office Industrial Museum, Mr. Murray had formed any opinion on the question whether a quality of light approaching daylight in colour value was more restful to the eyes than the uncorrected artificial lighting. He himself rather preferred the corrected light, but some people went much further—whilst others disliked the daylight effect, and even desired light of a yellowish tint.

Dr. S. ENGLISH (*communicated*):—Mr. Murray merits the thanks of the society for having so clearly shown the need for satisfactory lighting as an ally in the avoidance of accidents in factories, but I think he would add to the value of his paper and would materially help lighting engineers if he would tell them exactly where flame-proof lighting fittings must be employed, or alternatively, direct their attention to regulations governing their use.

While on this subject, I feel I must rebut a statement made earlier in the discussion to the effect that flame-proof ligthing fittings were necessarily inefficient. If properly designed, there is no reason why flame-proof fittings should be any more inefficient than any other enclosed industrial fittings. As a matter of fact, fittings of the type which Mr. Murray used (as a slide) to illustrate his paper happen to be very efficient, and incidentally give a full 30 deg. cut-off—thus completely avoiding glare and permitting full use to be made of the illumination provided on the working plane.

Mr. HOWARD LONG (*communicated*):—Firstly, I should like to stress the value of such a paper coming from an independent source. True we have met previously some of the facts given, but they have always been expounded by those who, it might be said, were biased.

Secondly, one cannot emphasise too strongly the importance of investigating the seeing task which is mentioned by the author under " Accuracy in Funda-

mentals." We have heard it claimed so often that general lighting is all that is necessary, but many years of study of seeing tasks has confirmed the work of Luckiesh and that of Beuttell and others, that there are many factors such as direction and quality of light, contrast, brightness, size, etc., to be considered. Localised general illumination, therefore, usually proves more satisfactory and, superimposed on this, supplementary lighting may be required for some individual tasks.

The only code of recommended illumination values in accordance with modern practice, is that issued recently by our Society and published in the "Transactions." This should be *the* guide. The author rather gives the impression that this code is based on initial values of illuminations, whereas in fact they are service values and initial values should be correspondingly higher. The use of dustproof lighting equipment is rapidly increasing in popularity and very largely eliminates depreciation, under which conditions the service values recommended in the code are approximately equal to the initial values.

Under "Natural and Artificial Illumination," the author puts forward as the ideal the factory without any roof, and thus open to the sky. I do not agree that this is the ideal. Daylight varies considerably in quantity, quality, diffusion, direction, etc., and, further, we have no control over it, whereas with artificial lighting we can provide exactly the best lighting to conform with the requirements from these several points of view.

I am afraid I cannot agree with the suggestion printed in italics, that the double-filament lamps might be used to provide two levels of illumination for supplementary lighting during the day and night respectively. Actually, I know of at least one very successful installation where a single reflector is used for each press on a low-voltage circuit and used during both day and night; but if an exceptional case arises, such as the author visualises, then it would appear more satisfactory to have two reflectors separately switched to control the level of illumination.

Reference is made under "Requirements in Certain Industries," to the regulations made under the Factory Act. It would be exceedingly valuable to illuminating engineers, if the author could, in his reply to the discussion, append references to these regulations and to the industries involved. In addition to those requirements given for wood-working machinery, the regulations specify that no glaring light-source should be located in the vicinity of the machinery.

Under "Shadow Conditions," the author gives some very useful information on a subject which is now becoming more fully appreciated, but I do not agree that in all cases the light should be directed on to the work in the same direction as that in which the worker is looking. This was at one time my view, but subsequent practical tests, an example of which I gave in the inspection of leather in a formal meeting last session, showed the necessity of the light coming in the opposite direction. In such a case it is, of course, necessary, where polished surfaces are involved, to reduce the brightness of the source to a very low level, as is indicated in the paper under the "Inspection of Polished Surfaces." There are many problems and many solutions. No generalised statement can be made regarding the most satisfactory method.

The 'bus lamps, as recommended by the author under "Low-Voltage Lighting," are frequently too large for the purpose, especially in such cases as for sewing machines, and the motor-car side lamp is much more widely used. I do not agree with the low end of the range of general lighting given by the author, namely, 2-10 foot-candles, as the supplementary lighting with the low-voltage system provides localised values in the region of 50 foot-candles, and the contrast will be too high even with half this amount. It must be remembered that in a recent paper Lythgoe showed that the brightness of the work should only be slightly higher than that of the surroundings.

I fail to understand how, as indicated under "Natural Lighting," the use of prismatic window glass alters the angle at which the light reaches benches at the back of rooms, although I fully appreciate that such glass will materially affect the amount of light reaching such benches. Surely the line drawn between these benches and the windows will always have the same angle of elevation, whatever glass is used in the window?

Regarding "Maintenance," my experience is that soap and water are not sufficient for restoring lighting equipment to its original efficiency, but that a special compound is necessary. Reflectors may look clean after washing in the ordinary way, but on testing in an integrating photometer, it will be found that they are not optically clean.

Mr. E. W. Murray, in replying, said that he was concerned as to what degree of extra illumination should be provided if persons having subnormal vision were to be catered for. It was far easier, he suggested, that the workers concerned should have their vision corrected to normal; the illuminating engineers could then at least start on a common basis, and the persons whose vision had been corrected would not suffer further deterioration of their eyes.

Commenting on the remarks of Mr. Shaw, he added that the trades unions were interested in good industrial lighting and that he received quite a number of inquiries from them concerning the lighting which should be provided for different classes of work.

He was in complete agreement with Mr. Shaw's plea that cheap reflectors should be made available readily to the public, and said that since the use of the shallow conical reflector could not be prohibited nothing would please him better than to have arrangements made whereby they could be destroyed as soon as they were produced!

Mr. Murray agreed with Mr. Ackerley that directional lighting which would give shadow effects was necessary in many cases. For instance, in drilling, the drill must be on the centre pop, and where there

was good general lighting the centre pop disappeared. For printing and embossing it was also necessary to provide directional light in order to give shadow.

He disagreed, however, that artificial lighting from outside, through the windows, was a success. It was very trying to the eyes, particularly in cases where the bottom portion of a window was almost as brightly illuminated as the top portion, and those working in such a room felt that there was something wrong; it was to some extent a psychological problem. It was easier to handle the lighting of a room from inside, especially where the room was four or five storeys above the ground. The maintenance and cleaning of the outside lights would be a cold job at times.

When referring to the constancy of artificial daylight he had had in mind its quality. In this connection he referred to a seed sorter, who had complained that on one day he could work for only twenty minutes because he was dependent on natural daylight, and throughout practically the whole day fleecy clouds had affected its colour so much that he could not work.

Mr. Cooper's remark in regard to the necessity for fuses on the low-tension side was quite correct, especially on the better or more efficient type of transformer. The British Standards Institution was preparing a specification for low-voltage transformers, so that it was probable that before long there should be available on the market a much better class of transformer. They would give better regulation, and there would be all the more need for fuses on the low-tension side.

Mr. Murray explained the fact that opaque reflectors could give quite pleasant effects in factories where the work and the floors were reasonably light in colour, because, if the illumination were good, a sufficient amount would be reflected into the upper portions of the factories or shops. In engineering works, etc., however, where the benches were dark and the floors were probably covered with oil and dirt (dark), one should use reflectors which would allow a proportion of the light from the light sources to be directed to the upper portions of the shops.

His point with regard to the elimination of glare was that glare not only reduced the efficiency of the illumination but also entailed more fatigue upon the operators.

Referring to the question of accidents, Mr. Murray said his point was that it was difficult to get those who had to handle electrical apparatus to bear in mind all the time the snags arising from the misuse of the plant. Good apparatus badly fitted or poorly maintained was a serious risk.

In regard to remarks on the comparative effect of natural and artificial light, Mr. Murray agreed that if we could reproduce the colour of normal daylight, with the mixture of red and north light, it would be of distinct advantage. Incidentally, because it was whiter than other light, it would give greater colour contrasts, which was of advantage in reading, for instance. To illustrate that he referred to a case in which some printing premises were illuminated with 60-watt metal filament lamps in semi-indirect lighting fittings. After two or three months the men had complained that the illumination was insufficient. Thereupon the lamps were re-replaced by 60-watt gas-filled lamps, and although the actual illumination was lower than before, it proved to be quite satisfactory. He believed it was due to the fact that the light was whiter than that of the metal filament lamps, and, therefore, gave greater contrasts.

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